Effects of Radio Channel on Networking Performance

Outputs

- Models of bit, frame, and packet error random processes.
- Quantitative analysis of effects of radio channel on network performance.
- Estimation of the radio channel's impact on spectral capacity.

The Institute is a recognized leader in radio channel measurement, modeling, and analysis. In the past 10 years this leadership has included work in characterizing multipath in personal communication services (PCS) and wireless local area network (WLAN) frequency bands as well as man-made noise at VHF and UHF frequencies. Such knowledge is essential for the development of robust mobile radio links. For example, development of new adaptive equalizers for modern, wide-bandwidth mobile radio links would not be possible without radio channel multipath measurement, modeling, and analysis.

Wireless network hosts that access the Internet are proliferating. IEEE 802.11 "WiFi" WLAN and 2.5/3rd generation PCS general packet radio service (GPRS) are but two examples. Recent research has shown that the radio channel can significantly degrade network performance by decreasing throughput, increasing delay, and losing packets. This degradation ultimately limits the usefulness of allocated spectrum.

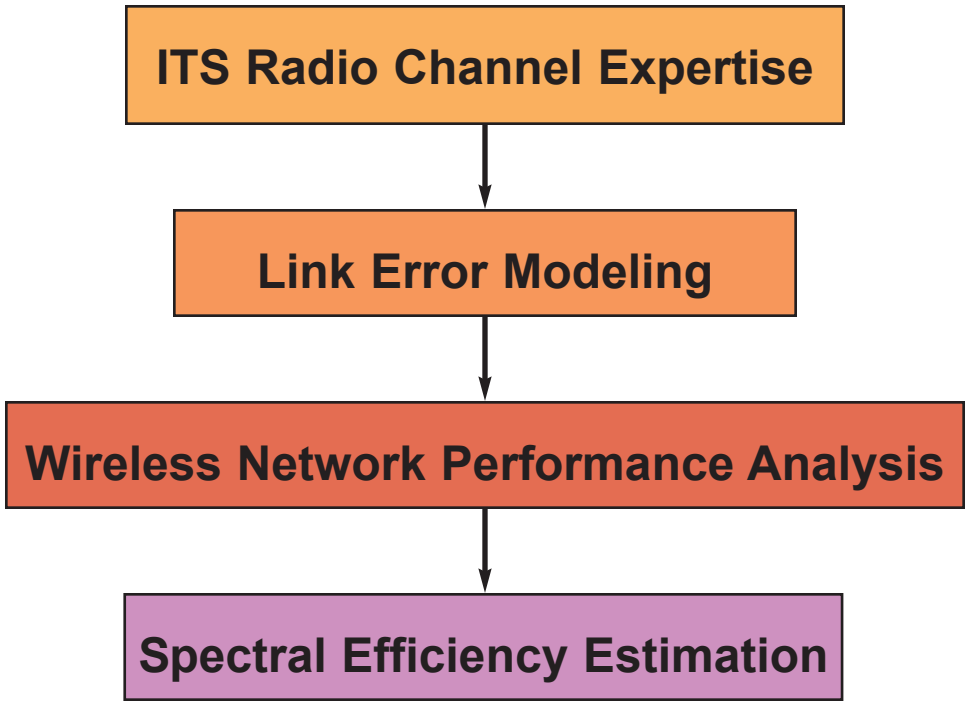
ITS is currently striving to translate its radio channel expertise into information that helps designers to improve the reliability and regulators to estimate the spectral efficiency of wireless networks. This is being accomplished by focusing on three tasks — (1) accurate modeling of the radio link bit, frame, and packet error processes resulting from radio channel impairments, (2) investigation of analytic techniques that correlate network performance to these error processes, and (3) computation of wireless network spectral capacities that account for these error processes.

Previous work included development of a radio link simulator incorporating multipath radio channel impairments. In FY 2004, this simulator was used to model bit and frame error processes caused by radio channel multipath. Initially, two frequency selective multipath radio channels were investigated. The first radio channel, referred to as the Hufford channel, had a direct path in addition to diffuse multipath created by a number of paths with independent Rayleigh fading processes. The second radio channel, referred to as the Gaussian wide sense stationary uncorrelated scattering (GWSSUS) channel, had only diffuse multipath. Bit and frame error processes due to the Hufford channel had independent, geometrically distributed time intervals. The error process due to the GWSSUS channel was markedly different.

In order to understand these differences we turned the investigation towards the analysis of the Rayleigh fading channel. Previous research has shown that the amplitudes of the Rayleigh fading channel can be modeled as a first-order Markov process where the current amplitude is dependent only on the amplitude of the previous sample. We hypothesized that the differences between the error processes may be due to the memory introduced by the first order Markov process.

We began our research by investigating the claim that the amplitude process was a first-order Markov process. The results of this investigation, currently in IEEE review, clearly demonstrated that only a fraction of the information needed to predict the current amplitude is in the previous sample and a more complex model is required to include information in earlier samples. In FY 2005, ITS plans to investigate the impact of this finding on bit and frame error processes used in network analysis and simulation.

In FY 2003, ITS completed a comprehensive search of professional literature which defined the scope of the effects of the radio channel on network tasks. This search indicated that queuing, routing, and end-to-end transmission tasks were the most severely compromised by the effects of the radio channel.



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Today, simulation is often used to correlate the effects of the radio channel on the performance of these tasks. However, our search also pointed out that validation of simulation results, either through experimentation or theoretical analysis, is difficult and not commonly done.

In FY 2005, we will explore new methods for validating wireless network performance simulations. One approach to this problem is to find ways of incorporating the effects of the link error process into theoretical expressions which are commonly used to predict wired network throughput and delay. These analytic expressions include Burke's theorem which is commonly used to investigate the behavior of two queues, or Jackson's theorem which is commonly used to investigate the behavior of a group of queues.

Spectrum capacity is often measured in terms of the number of voice channels which can be supported per unit area. With the proliferation of the Internet, it will become important to measure spectrum capacity in terms of the number of end-to-end packet transmission circuits the spectrum can support. This estimate will clearly be dependent on the effects of the radio channel on network tasks such as queuing, routing, and end-to-end transmission. In FY 2005, the impact radio channel impairments have on computing the spectrum capacity of packet transmission circuits will be investigated.

Recent Publication

R. Dalke and G. Hufford, "Analysis of the Markov character of a general Rayleigh fading channel," submitted to *IEEE Transactions on Vehicular Technology*.

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